Beach Nourishment on Puget Sound: A Review of Existing Projects and Potential Applications

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Abstract

Coastal planners and resource managers increasingly consider beach nourishment a viable alternative to conventional shoreline armoring for addressing erosion on Puget Sound. Few projects have been well documented, however, and technical information on the geomorphology and engineering of gravel beaches is limited. In this project, we evaluated approximately thirty nourishment projects on Puget Sound through field investigation, interviews, analysis of historical conditions, and review of project records. We specifically looked at how the projects' geologic settings affected their design and success. We found that nourishment has been employed in highly diverse situations, from residential sites to industrial cleanup actions, and at many scales, from small pocket beaches to large beach feeding projects. A majority consist of gravel beaches in public parks. Most occur on low-lying shorelines, whereas few have been constructed on bluff-backed beaches. Nourishment has been used for erosion control, recreational enhancement, mitigation for armoring, and as a component in biological enhancement efforts. We conclude that nourishment is an important tool in addressing shoreline problems on Puget Sound, but that effective application requires improved engineering and regulatory guidance, systematic monitoring, and increased knowledge of the geomorphologic processes acting on individual sites.

Introduction

Puget Sound includes more than 2000 miles of highly convoluted and heterogeneous shoreline, much of it consisting of mixed sand and gravel beaches and backed by eroding bluffs of glacial sediments. This coastline represents a rich and diverse ecological zone, but it is also the focus of intense development pressure as the region's population expands and demand increases for shoreline property. Coastal managers and resource planners are faced with guiding activities along the shoreline to accommodate new development safely, but with minimal impacts on critical biological resource and on adjacent shorelines. Historically, erosion control and shoreline development was facilitated with bulkheads and revetments. As awareness of the adverse impacts of these structures has grown, interest in more benign approaches has increased.

Beach nourishment is the intentional addition of sand and gravel to the beach profile. Its most familiar application is on sandy, open ocean coasts where large volumes of dredged sand may be placed to restore an eroded beach or to provide storm protection to upland development. On Puget Sound, nourishment projects are typically smaller and often employ gravel from upland sources. A variety of terms are used on the Sound to describe nourishment, including beach enhancement, beach replenishment, beach restoration, and beach feeding. Adding gravel and similar modification of bottom substrate to enhance shellfish production, capping of contaminated subtidal sediments, and the infilling of coarse armor rock with fine sediment for the purpose of improving fish habitat are not considered beach nourishment.

Relatively little has been written about beach nourishment on Puget Sound (Shipman 1996). Terich and others (1991) reviewed the published literature on nourishment with attention to those aspects relevant to Puget Sound. Several individual projects have been described, including West Point in Seattle (Domenowske 1987), Point Roberts (Layton 1987), Ediz Hook (Galster and Schwartz 1990), Bayview State Park (Johannessen 1996), and Lincoln Park (Antrim and others 1996). Descriptions of projects are also found in Downing (1983), Macdonald and others (1994), Zelo and others (2000), and Shipman and others (2000). Johnson and Bauer (1987) describe typical gravel beach techniques on Puget Sound.

The purpose of this paper is to summarize how beach nourishment has been applied in Puget Sound and to identify factors that affect the implementation and the success of nourishment projects. Our objectives are

to increase awareness of both the limitations and opportunities posed by this technique and to suggest new areas where we believe nourishment might be successfully applied.

Beach Nourishment Projects

We surveyed nourishment projects through field visits, review of documents, and interviews. We have been personally involved in a technical advisory and regulatory review role on many of the projects carried out since 1990, and much of our material has been drawn from this experience. Documents reviewed include permit records, design submittals, project reports, and published accounts where available. Gathering information was not always straightforward. Even relatively recent projects often lacked key documentation. Projects often undergo design changes after project approval and these revisions are rarely recorded. Few projects have been monitored, and of those that have, much has been informal and qualitative.

We identified more than 30 beach nourishment projects carried out on Puget Sound, most constructed within the last two decades. The scale of projects ranges broadly, from small artificial pocket beaches involving only a few hundred cubic yards of sediment to much larger projects requiring hundreds of thousands of cubic yards of material. We found enormous diversity in the scale, construction, and the application of nourishment on the Sound. Almost all projects, however, shared the common objective of providing erosion control while maintaining or improving ecological and recreational conditions on the beach itself.

Figure 1a. Jetty Island, Everett. Artificial spit/berm and tidal lagoon created with sand dredged from Snohomish River, seen in background [WA Department of Ecology 1993].

The applications of nourishment projects on Puget Sound have been highly diverse, reflecting different geologic settings and different project objectives. This variation is illustrated well by the contrast between Jetty Island in Everett and Thea's Park in Tacoma (Figures 1a and 1b). More than 300,000 cubic yards of dredged sand were used in the Jetty Island project to create an artificial sand spit that in turn allowed for the formation of lagoon, salt marsh, and backshore dune habitats. In contrast, Thea's Park used a few hundred cubic yards of gravel, in conjunction with a stepped concrete seawall, to create a small artificial pocket beach along a shoreline highly modified by past industrial development.

Figure 1b. Thea's Park, Tacoma. Gravel pocket beach formed in an embayment along a heavily modified and filled shoreline.

A majority of the nourishment projects we examined consisted of enhanced gravel beaches in public parks. The predominance of gravel beach projects reflects the underlying character of Puget Sound's coarse-grained beaches, the local success of gravel beach berms in reducing erosion and the availability of gravel from upland sources. Public parks are common settings for nourishment projects for several reasons. Parks often have sufficiently long shorelines to make effective nourishment more successful. There may be more flexibility to consider softer or more experimental approaches. Significantly, parks planners often value the beach, and easy access to it, highly and are also accustomed to trying to balance multiple objectives, including environmental benefit, erosion control, and recreational use.

Most projects in this study occur along low shorelines, either on barrier beaches or on artificial fill (Figure 2). In part, this is because nourishment has been a popular approach in public parks and many waterfront parks occur on low-lying shores or along historically filled urban shorelines. In addition, practical implementation of nourishment and its likelihood of success without extensive maintenance may be higher in low bank locations. Most projects occurred where anthropogenic actions had accelerated pre-development erosion rates, either by reducing the supply of littoral drift to the site or by placing fill waterward of the beach's natural profile.

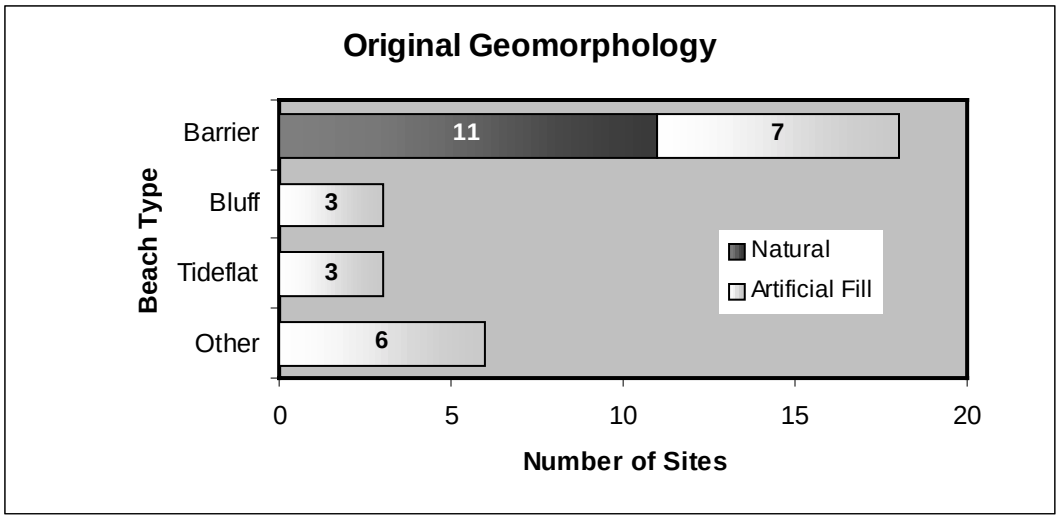

Figure 2. Geomorphologic setting of Puget Sound beach nourishment projects.

Only one of the projects we reviewed occurred along a naturally eroding shoreline bluff (Place Eighteen, Bainbridge Island). Two others, Lincoln Park in Seattle and Luhr Beach in Thurston County, are backed by bluffs, but nourishment protects historic fill, not the bluff itself. Along Lummi Shore Drive north of Bellingham, nourishment has been employed as mitigation for lost beach and sediment in front of a major revetment that in turn protects an eroding bluff.

Nourishment projects may be classified by several characteristics, including size, sediment type used, project objectives, or geologic setting. Each of these has limitations, particularly in that fundamentally different projects get grouped together. For example, if size is a criterion, the large Jetty Island and Ediz Hook projects are similar, although the former is a beach created from dredged sand and the latter is a cobble beach feeding project.

In Table 1, we employ a combination of geologic setting and the project's purpose to develop generalized categories of beach nourishment projects. We feel this provides a useful indication of the range of nourishment applications on the Sound. These divisions are not absolute, however, and opinions might vary on both the labels and on how projects are classified. Beach feeding differs from gravel nourishment primarily in the volumes of material placed and the recognition that large portions of the material will move offsite and need to replaced on a regular basis. Bypass operations are ostensibly beach feeding projects, but specifically involve moving sediment past an obstruction to littoral drift such as a harbor entrance. Gravel erosion protection involves the additions of minor amounts of sediment to stem minor erosion, but involve little project design. Pocket beach enhancements are those where material is largely confined within a small embayment, typically along a heavily modified and reconfigured shoreline.

Although many projects employ nourishment in combination with groins or bulkheads, Sunnyside Beach in Steilacoom represents a more complex engineering approach, using a unique combination of parallel bulkheads in one segment and creating a small cove in another. Jetty Island, and to some extent the large sand fill at Neah Bay, involve creation of entirely new beaches. Finally, nourishment has been used to mitigate the impacts of hard structures. At Lummi Shore Drive, nourishment has been used to address the loss of upper beach habitats in front of a massive riprap revetment. At a smaller scale, for several years, habitat biologists with the Washington Department of Fish and Wildlife have required that a small wedge of pea gravel be placed on the beach in front of recent bulkhead projects, in part to mitigate disturbance of beach substrate during construction.

Table 1. Examples of beach nourishment applications on Puget Sound.

Category	Examples
Gravel nourishment	Lincoln Park, Seattle Tolmie State Park, Thurston County Samish Beach, Skagit County Salsbury Point, Kitsap County West Point, Seattle
Beach feeding	Ediz Hook, Port Angeles
Sediment bypass	Keystone Harbor, Island County Point Robert Marina, Whatcom County
Gravel erosion protection	Potlatch State Park, Mason County
Pocket beach enhancement	Seacrest Park, Seattle Thea's Park, Tacoma Brackett's Landing. Edmonds
Engineered hybrid	Sunnyside Beach, Steilacoom
Artificial beach	Jetty Island, Everett
Environmental mitigation	Lummi Shore Drive, Whatcom County WDFW bulkhead mitigation

Limitations

Beach nourishment, although a useful tool in some situations, has significant limitations. As with any site-specific solution, if erosion or chronic substrate changes are the result of sediment deficits within a littoral cell or due to human–induced changes in the local wave climate, nourishment may address a symptom without solving the underlying problem.

Beach nourishment only addresses shoreline problems related to beach sediment. Nourishment can enhance the functions of a natural sand or gravel beach and in so doing, can reduce erosion or can restore appropriate-sized substrate. Nourishment does not directly address the preservation of eelgrass or the restoration of riparian vegetation, although it may be an important component of more comprehensive projects aimed at these issues.

Effective application of nourishment requires space. Placing sediment on the existing intertidal profile shifts beach contours waterward, creating concerns for aquatic resource managers and biologists. Alternatively, if nourishment is to occur without waterward encroachment, it may be necessary to excavate into upland areas, conflicting with upland uses. In most cases, nourishment involves reducing the gradient of transition between the upland and lower intertidal areas. Where projects have succeeded, it was because the geometry of the site was favorable and because shoreline regulators and upland property owners were able to agree to both the waterward and landward extents of the project.

Beach nourishment, because it places a large volume of sediment directly on existing intertidal areas, results in significant initial disturbance. Little is known in this region about recovery rates of benthic communities following burial. If the placed material has a high proportion of fine sand, silt, and clay, turbidity may be a concern, either during construction or during the first significant wave action. In some cases, this can be reduced with judicious construction practices. Sedimentation can also be limited by using coarser material with fines selectively removed, but although there may also be engineering benefits of

choosing a coarser or better sorted gravel, the longer term biological impacts of leaving out the fine component may be negative. Nourishment projects may be inappropriate where concerns about short-term impacts cannot be balanced by expectations of long-term environmental improvement.

A nourished beach responds dynamically to storm waves, but cannot generally be designed with the same certainty as a conventionally engineered seawall or revetment. Nourishment projects, if not designed and maintained properly, may be more susceptible to damage from certain combinations of storm and tide events than equivalently designed hard structural solutions. Where the consequences of ineffective protection are extremely high, nourishment may not provide an engineer with adequate confidence to recommend their application.

Beach nourishment can address erosion concerns, but unless built unusually high or accompanied by a landward barrier, an artificial beach may not prevent backshore flooding during extreme high tides. Neither nourishment nor traditional seawalls will prevent failure of coastal bluffs where slope movement is related to geologic and hydrologic factors higher on the slope.

Among the most significant concerns about shoreline armoring is their cumulative role in reducing sediment supplies to beaches, thereby resulting in narrowing, lowering, and coarsening of the beach profile (Macdonald and others 1994; Thom and others 1994). This problem is largely related to armoring along eroding coastal bluffs, yet only one of the projects we reviewed specifically addressed bluff erosion. This indicates that nourishment, at least to date, has not been applied in the situation where there is greatest demand for alternate approaches to erosion control.

The lack of nourishment projects along eroding coastal bluffs reflects some practical limitations of beach nourishment. Nourishment design is not readily adapted to individual residential properties on high bank shoreline. Where long-shore sediment fluxes are high, property owners have little incentive to place sediment, given that in a single storm it may be moved several properties down the shore. In addition, high bank property and the threat of slope failure often results in a more conservative design scenario for an engineer and there is a strong incentive to recommend structural measures. Even if nourishment were proposed to protect coastal bluffs, there may be concerns about the logistical and environmental implications of individual property owners routinely adding additional sediment to their beaches.

Obstacles

Effective implementation of beach nourishment in the Puget Sound region faces a number of difficulties. These include limited awareness of nourishment applications, poor technical understanding of nourishment among engineers and contractors, regulatory concerns, and the need for long term commitments to maintenance and monitoring.

Despite the 30 or so nourishment projects carried out on Puget Sound, many technical professionals, resource planners, and members of the general public are not familiar with beach nourishment nor the principles of its application. Ironically, many of the most visited beaches in the Central Sound are the result of nourishment, yet part of their success may lie in the fact that many people cannot distinguish a natural beach from a nourished one. For example, the popular beaches of Lincoln Park, Discovery Park, and Golden Gardens in Seattle are all nourished (Shipman and others 2000).

Few consultants in the Puget Sound region have experience with beach nourishment or with the behavior of gravel beaches. The standard reference for coastal engineering work, the Corps of Engineers' *Shore Protection Manual* (USACE 1984), provides no technical guidance on designing gravel beaches and little advice on interpreting geomorphologic processes on the types of beaches found in this area. Many of the nourishment projects in the Puget Sound region reflect the design and influence of a single consultant, Wolf Bauer, who combined extensive experience with coarse-grained beaches with a strong commitment to preserving beaches and shorelines. Only recently have other consultants begun to design nourishment projects in the area.

Nourishment is regulated under several shoreline regulations, including the state Shoreline Management Act and Hydraulics Code and Section 404 of the federal Clean Water Act. Nourishment projects involve placing fill over intertidal areas and their construction can lead to significant disturbance to the existing benthic community. Nourishment generally shifts shoreline contours waterward, thereby violating strict interpretations of "no net loss" provisions. Many projects have involved secondary structures such as groins, which have long been viewed skeptically by shoreline managers. Whereas traditional armoring projects, particularly on residential property, often receive favorable considerations under shoreline regulations, nourishment typically does not. In addition, many seawalls and revetments can be constructed above Mean Higher High Water, therefore avoiding federal jurisdiction under Section 404, but most nourishment projects require placing material below this elevation.

As a consequence of these environmental concerns, nourishment projects often receive strict scrutiny, sometimes stricter than that received by more conventional erosion control applications. At the same time, many of these same authorities support policies that increasingly emphasize softer erosion control methods, including beach nourishment. This has created ambiguities for proponents of nourishment projects, although the degree to which it discourages such projects is not known.

Concerns about future maintenance obligations and potential long-term costs can also discourage nourishment proposals. Most projects will eventually require renourishment, whereas traditional structural solutions are typically promoted as requiring minimal maintenance. In addition, nourishment projects are increasingly expected to contain a monitoring element, in part to assist renourishment planning, but also to evaluate project impacts and performance.

Potential Applications

As understanding of nourishment increases, particularly among property owners and shoreline consultants, and as scrutiny of hard armoring increases, we expect that nourishment will be proposed, and approved, more frequently. There are several areas in which nourishment is currently relatively rare, but where we expect to see increased interest.

Flood and storm damage reduction

Nourishment of the uppermost portion of the beach profile, by enhancing the beach berm or creating a low backshore dune, may reduce flood and storm damage on low-lying coastal properties. An elevated berm crest can greatly reduce wave overtopping and the volume of debris rafted into the backshore on developed barrier beaches. Gravel berms can respond flexibly to storm action and can be maintained with additional gravel if significant erosion occurs. Such berms support native backshore vegetation and the natural accumulation of drift logs.

Shoreline bluffs

We noted earlier the conspicuous absence of nourishment projects along shorelines comprised of eroding bluffs. As discussed, there are practical reasons for this. On the other hand, nourishment, if carried out properly, may be a viable tool for reducing wave-induced erosion on high bank shorelines without adversely impacting sediment supplies to adjacent beaches. Such projects might involve regular additions of small volumes of gravel at individual properties, the design of community-scale beach feeding efforts, or in some more developed settings, might warrant consideration of much larger scale, berm construction projects such the Point Grey project in Vancouver, B.C. (Downie and Saaltinck 1983).

Temporary erosion control

Beach nourishment may be appropriate for addressing temporary erosion control. Sediment placed on a beach can provide protection to the backshore or to the toe of an eroding bank, yet it does not result in an irreversible change to the beach, allowing its use in situations where there are serious concerns about the long-term impact or precedent setting nature of a hard structure.

Shoreline erosion, no matter how predictable, is typically cast as an emergency. As a result, decisions get made rapidly and emotionally, standard review processes are ignored or expedited, and activities that

would be limited or prohibited under less urgent circumstances are approved. Nourishment, at least in some circumstances, may provide the short-term protection necessary to allow a more judicious review of alternatives.

One limitation to the increasing interest in using vegetative and biotechnical techniques to stabilize unstable coastal bluffs is that the toe of the slope must often be protected until plantings are well established. An artificial gravel berm may provide a practical way of achieving this protection without resort to the installation of permanent structural measures.

Beach feeding

At Ediz Hook, sediment was added to the beach with full knowledge that the material would gradually, but inextricably, move offsite. The need for regular renourishment was recognized as a necessary intervention to replace sediment supplies lost to historic shoreline modifications. There are other sites on Puget Sound where loss of natural sediment supplies has exacerbated erosion, adversely affecting nearshore habitats or and resulted in increased damage to structures. Long-term feeding programs might be designed that would address these issues through placement of material at the updrift end of a reach of shoreline, coupled with periodic renourishment based on systematic monitoring.

Restoration and ecological enhancement

The restoration of the beach, backshore, and associated back-barrier wetlands at Golden Gardens Park in Seattle required nourishment to reestablish the natural berm and to protect the wetlands from erosion. At Jetty Island, the lagoon and salt marsh resulted directly from the creation of an artificial sand spit. At the Dickman Mill site in Tacoma, recent restoration of tidal wetlands has been carried out in conjunction with the creation of an artificial berm and beach nourishment. Particularly in heavily urbanized settings, we may expect to see nourishment increasingly incorporated in proposals to restore coastal habitats.

Mitigation

Shoreline erosion control measures can displace or eliminate critical portions of the upper beach. They may reduce or eliminate natural sediment supplies to the beach. Marina entrances, jetties, and shoreline fills can reduce beach habitat or disrupt littoral sediment movement. Nourishment provides a mechanism for mitigating some of the impacts of these projects, at least where those impacts are directly related to littoral sediment supply and movement. Bypassing of beach sediment, currently only applied at the Point Roberts Marina and at Keystone Harbor, may be an appropriate way of dealing with the impacts of existing marina entrance channels and dredging. There may be opportunities to feed reaches of shoreline heavily impacted by erosion control structures in order to maintain beach habitats, such as is being done along Lummi Shore Drive north of Bellingham.

Conclusions

Beach nourishment has been used successfully throughout Puget Sound to protect eroding shorelines, restore beaches, and enhance shoreline functions in degraded areas. The variety of projects is large, although a majority are relatively small gravel beaches. As understanding of nourishment improves and as obstacles to its effective implementation are overcome, we expect to see nourishment incorporated in a broader range of shoreline projects, including community scale beach-feeding projects, erosion reduction on coastal bluffs, temporary erosion control, and a variety of habitat enhancement applications.

References

Antrim, L., Dillon, J., and Thom, R., 1996, Lincoln park shoreline erosion control project: Monitoring for impacts on eelgrass, bivalves, and bull kelp. Proceedings of the Fifteenth International Conference of the Coastal Society, Seattle, Washington. 426-431.

Domenowske, R. S., 1987, Municipality of Metropolitan Seattle West Point Beach Restoration. Coastal Zone '87. 2141-2152.

Downie, K. A., and Saaltink, H., 1983, An artificial cobble beach for erosion control. Coastal Structures '83. American Society of Civil Engineers. 846-859.

Downing, J., 1983, The Coast of Puget Sound: its processes and development. University of Washington, Washington Sea Grant, Seattle.

Galster, R. W., and Schwartz, M. L., 1990, Ediz Hook - A case history of coastal erosion and rehabilitation. Journal of Coastal Research Special Issue, **6:** 103-113.

Johannessen, J., 1996, Beach nourishment at Bay View State Park, Washington. Proceedings of the Fifteenth International Conference of the Coastal Society, Seattle, Washington. 438-447.

Johnson, L., and Bauer, W., 1987, Beach stabilization design. Coastal Zone '87. American Society of Civil Engineers, New York. 1432-1445.

Layton, J. A., 1987, Case history of a Puget Sound bypass operation. Coastal Sediments '87, Seattle. American Society of Civil Engineers. 1259-1273.

Macdonald, K., Simpson, D., Paulsen, B., Cox, J., and Gendron, J., 1994, Shoreline armoring effects on physical coastal processes in Puget Sound, Washington. Shorelands and Water Resources Program, Washington Department of Ecology. Olympia, Washington.

Shipman, H., 1996, Puget Sound Beach Replenishment. Fifteenth International Conference of the Coastal Society, Seattle, Washington. 448-454.

Shipman, H., Stoops, K., and Hummel, P, 2000, Seattle Waterfront Parks: Applications of Beach Nourishment. Field trip guide for Washington Coastal Planners Group, July 20, 2000. Washington Department of Ecology. Olympia, Washington.

Terich, T. A., Schwartz, M. L., and Johannessen, J., 1991, Coastal erosion management: Annotated bibliographies on shoreline hardening effects, vegetative erosion control, and beach nourishment. Washington Department of Ecology. Olympia, Washington.

Thom, R. M., Shreffler, D. K., and Macdonald, K., 1994, Shoreline armoring effects on coastal ecology and biological resources in Puget Sound, Washington. Shorelands and Water Resources Program, Washington Department of Ecology. Olympia, Washington.

U.S. Army Corps of Engineers, 1984, Shore Protection Manual. United States Army Corps of Engineers, Coastal Engineering Research Center, Department of the Army. Vicksburg, Mississippi.

Zelo, I., Shipman, H., and Brennan, J., 2000, Alternative Bank Protection Methods for Puget Sound Shorelines. Shorelands and Environmental Assistance Program, Washington Department of Ecology. Olympia, Washington.